REMARKS

The foregoing Amendment improves the form of the application without adding new matter.

Respectfully submitted,

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PATENT
Attorney Docket No. 401142/TAKADA

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

TADA et al.

Art Unit: Unknown

Application No.: Unknown

Examiner: Unknown

Filed: March 27, 2001

For: OPTICAL MODULATOR, METHOD FOR FABRICATING THE SAME, AND PHOTONIC SEMICONDUCTOR DEVICE

SPECIFICATION, CLAIMS AND ABSTRACT AS PRELIMINARILY AMENDED

Amendments to the paragraph beginning at page 4, line 4:

However, optical modulators designed to execute modulation at speeds as high as 40 Gbps or more are required to have an element ~~capacity~~ capacitance of 0.1 pf or less. In the conventional optical modulator structure, the element ~~capacity~~ capacitance is reduced using a thicker polyimide layer 214. This has posed a problem: the polyimide layer 214 is difficult to form.

Amendments to existing claims:

1. (Amended) An optical modulator comprising:

a semi-insulating semiconductor substrate with a principal plane ~~partially~~ including ~~an~~ a partially exposed surface;

an optical waveguide ridge which is disposed on said semiconductor substrate and which includes a first ~~clad~~ cladding layer of a first conductivity type, an optical-

absorption layer, and a second ~~clad~~ cladding layer of a second conductivity type, said optical waveguide ridge further having a side with a flat portion extending uniformly from a top of the ridge to said semiconductor substrate, the flat portion being in contact with the exposed surface of said semiconductor substrate;

a dielectric film which covers said optical waveguide ridge and said semiconductor substrate and which has a first opening ~~made~~ at the top of said optical waveguide ridge and a second opening ~~made~~ in a region of said semiconductor substrate other than the exposed surface;

a first electrode disposed on said dielectric film and mounted through ~~said~~ the first opening on the top of said optical waveguide ridge, said first electrode further extending on the flat portion of said optical waveguide ridge ~~while~~ in ~~close~~ contact with a surface of said dielectric film, said first electrode further having one end ~~thereof established~~ on said semiconductor substrate ~~through~~ at the exposed surface ~~thereof~~; and

a second electrode disposed on said semiconductor substrate and connected to the first ~~clad~~ cladding layer through the second opening ~~of~~ in said dielectric film.

2. (Amended) ~~An~~The optical modulator according to claim 1, wherein said semiconductor substrate has exposed surfaces on both sides of said optical waveguide ridge, wherein said optical waveguide ridge has the flat portion on both sides ~~thereof respectively~~ and wherein said first electrode extends over both sides of said optical waveguide ridge, two ends of said first electrode being disposed respectively on the exposed surface of said semiconductor substrate.

3. (Amended) ~~An~~The optical modulator according to claim 1, wherein the first ~~clad~~ cladding layer ~~further~~ has an extension that extends onto a region of said semiconductor substrate located outside said optical waveguide ridge and excluding the region where said first electrode is disposed.

4. (Amended) ~~An~~The optical modulator according to claim 2, wherein the first ~~clad~~ cladding layer ~~further~~ has an extension that extends onto a region of said

semiconductor substrate located outside said optical waveguide ridge and excluding the region where said first electrode is disposed.

5. (Amended) ~~An~~The optical modulator according to claim 3, wherein said second electrode is disposed through said second opening on the extension of the first ~~clad~~ cladding layer.

6. (Amended) ~~An~~The optical modulator according to claim 4, wherein said second electrode is disposed through said second opening on the extension of the first ~~clad~~ cladding layer.

7. (Amended) ~~An~~The optical modulator according to ~~claims~~ claim 1, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

8. (Amended) ~~An~~The optical modulator according to ~~claims~~ claim 2, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

9. (Amended) ~~An~~The optical modulator according to ~~claims~~ claim 3, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

10. (Amended) ~~An~~The optical modulator according to ~~claims~~ claim 4, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

11. (Amended) ~~An~~The optical modulator according to claim 1, further comprising a conductive layer of said first conductivity type ~~furnished~~ disposed over a part of said semiconductor substrate including a region under said optical waveguide ridge and excluding the region where said first electrode is ~~provided~~ located, said second electrode being ~~formed~~ disposed on said semiconductor layer through ~~said~~ the second opening ~~of~~ in said dielectric film.

12. (Amended) An optical modulator according to ~~claims~~ claim 1, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

13. (Amended) An optical modulator according to ~~claims~~ claim 2, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

14. (Amended) An optical modulator according to ~~claims~~ claim 3, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

15. (Amended) An optical modulator according to ~~claims~~ claim 4, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

16. (Amended) A photonic semiconductor device comprising:

an optical modulator having~~:~~:

a semi-insulating semiconductor substrate with a principal plane ~~partially~~ including ~~an~~ a partially exposed surface,

an optical waveguide ridge which is disposed on said semiconductor substrate and which includes a first ~~clad~~ cladding layer of a first conductivity type, an optical-absorption layer, and a second ~~clad~~ cladding layer of a second conductivity type, said optical waveguide ridge further having a side with a flat portion extending uniformly from a top of the ridge to said semiconductor substrate, the flat portion being in contact with the exposed surface of said semiconductor substrate,

a dielectric film which covers said optical waveguide ridge and said semiconductor substrate and which has a first opening ~~made~~ at the top of said optical waveguide ridge and a second opening ~~made~~ in a region of said semiconductor substrate other than the exposed surface,

a first electrode disposed on said dielectric film and mounted through ~~said~~ the first opening on the top of said optical waveguide ridge, said first electrode further extending on the flat portion of said optical waveguide ridge ~~while~~ in ~~close~~ contact with a surface of said dielectric film, said first electrode further having one end ~~thereof established~~ on said semiconductor substrate ~~through~~ at the exposed surface ~~thereof~~, and

a second electrode disposed on said semiconductor substrate and connected to the first ~~clad~~ cladding layer through the second opening ~~of~~ in said dielectric film; and

a semiconductor laser device aligned in optical axis with the optical absorption layer of said optical modulator.

17. (Amended) ~~A~~The photonic semiconductor device according to claim 16, wherein said semiconductor laser device is a ridge type device having an optical waveguide ridge disposed on a semi-insulating semiconductor substrate, said semiconductor laser device and said optical modulator being mounted on ~~the same~~ said substrate.

18. (Amended) An optical modulator fabricating method including ~~the steps of~~:

forming ~~firstly~~ a first ~~clad~~ cladding layer of a first conductivity type, an optical absorption layer, and a second ~~clad~~ cladding layer of a second conductivity type on a semi-insulating semiconductor substrate;

forming ~~secondly~~ by ~~photolithograpy~~ photolithography and etching an exposed surface of the semiconductor substrate as well as an optical waveguide ridge which has a side with a flat portion ~~stretching~~ extending uniformly from a top of the ridge to the semiconductor substrate, the flat portion being ~~brought into~~ in contact with the exposed surface of the semiconductor substrate;

forming ~~thirdly~~ a dielectric film over the semiconductor substrate and ~~a~~ first and ~~a~~ second ~~opening~~ openings through the dielectric film, the first opening being made at the top of the optical waveguide ridge, the second opening being made in a region of the semiconductor substrate excluding the exposed surface ~~thereof~~;

forming ~~fourthly~~ a first electrode through the first opening on the top of the optical waveguide ridge ~~in such a manner that the first electrode extends~~, extending on the flat portion of the optical waveguide ridge ~~while~~ and in ~~close~~ contact with a surface of the dielectric film, the first electrode further having one end ~~thereof formed~~ on the semiconductor substrate ~~through~~ at the exposed surface ~~thereof~~; and

forming ~~fifthly~~ a second electrode connected to the first ~~clad~~ cladding layer through the second opening ~~of~~ in the dielectric film.

19. (Amended) ~~An~~The optical modulator fabricating method according to claim is, wherein ~~the second step~~ forming the exposed surface of the semiconductor substrate includes forming exposed surfaces of the semiconductor substrate on both sides of said optical waveguide ridge, as well as the flat portion ~~respectively~~ on both sides of the optical waveguide ridge, and wherein ~~the fourth step~~ forming a first electrode includes ~~causing~~ forming the first electrode to extend over both sides of the optical waveguide ridge, ~~and~~ the first electrode having two ends ~~of the first electrode formed respectively~~ on the exposed surfaces of the semiconductor substrate.

20. (Amended) ~~An~~The optical modulator fabricating method according to claim 18, wherein ~~said~~ forming of the first ~~step~~ cladding layer is preceded by ~~the step of~~ forming a conductive layer of ~~said~~ the first conductivity type over part of the semi-insulating semiconductor substrate, ~~wherein said second step~~ forming the exposed surface of the semiconductor substrate includes forming an exposed surface of the conductive

layer while forming the exposed surface of the semiconductor substrate, and ~~wherein, said fifth step~~ forming the second electrode includes forming the second electrode on the conductive layer through the second opening.

Amendments to the abstract:

ABSTRACT OF THE DISCLOSURE

An optical waveguide ridge ~~14~~ has a side with a flat portion ~~14a stretching~~ extending uniformly from a top of the ridge to a surface of a semiconductor substrate ~~12~~, the flat portion ~~14a~~ being in contact with an exposed surface of the substrate ~~12~~. A p-type electrode ~~22 is extended~~ extends from the top of the optical waveguide ridge ~~14~~ downward ~~while~~ in ~~close~~ contact with a dielectric film ~~16 furnished~~ on the flat portion ~~14a~~ of the optical waveguide ridge ~~14~~. The p-type electrode ~~22 is~~ further ~~extended~~ extends over the dielectric film ~~16 on to~~ onto the exposed surface of the semiconductor substrate ~~12~~ where an end of the electrode ~~22~~ is ~~formed into~~ a bonding pad ~~22a~~.

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CLAIMS PENDING AFTER PRELIMINARY AMENDMENT

1. An optical modulator comprising:

a semi-insulating semiconductor substrate with a principal plane including a partially exposed surface;

an optical waveguide ridge which is disposed on said semiconductor substrate and which includes a first cladding layer of a first conductivity type, an optical-absorption layer, and a second cladding layer of a second conductivity type, said optical waveguide ridge further having a side with a flat portion extending uniformly from a top of the ridge to said semiconductor substrate, the flat portion being in contact with the exposed surface of said semiconductor substrate;

a dielectric film which covers said optical waveguide ridge and said semiconductor substrate and which has a first opening at the top of said optical waveguide ridge and a second opening in a region of said semiconductor substrate other than the exposed surface;

a first electrode disposed on said dielectric film and mounted through the first opening on the top of said optical waveguide ridge, said first electrode further extending on the flat portion of said optical waveguide ridge in contact with a surface of said

dielectric film, said first electrode further having one end on said semiconductor substrate at the exposed surface; and

a second electrode disposed on said semiconductor substrate and connected to the first cladding layer through the second opening in said dielectric film.

2. The optical modulator according to claim 1, wherein said semiconductor substrate has exposed surfaces on both sides of said optical waveguide ridge, wherein said optical waveguide ridge has the flat portion on both sides and wherein said first electrode extends over both sides of said optical waveguide ridge, two ends of said first electrode being disposed respectively on the exposed surface of said semiconductor substrate.

3. The optical modulator according to claim 1, wherein the first cladding layer has an extension that extends onto a region of said semiconductor substrate located outside said optical waveguide ridge and excluding the region where said first electrode is disposed.

4. The optical modulator according to claim 2, wherein the first cladding layer has an extension that extends onto a region of said semiconductor substrate located outside said optical waveguide ridge and excluding the region where said first electrode is disposed.

5. The optical modulator according to claim 3, wherein said second electrode is disposed through said second opening on the extension of the first cladding layer.

6. The optical modulator according to claim 4, wherein said second electrode is disposed through said second opening on the extension of the first cladding layer.

7. The optical modulator according to claim 1, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

8. The optical modulator according to claim 2, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

9. The optical modulator according to claim 3, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

10. The optical modulator according to claim 4, further comprising a dielectric layer located between said dielectric film and said first electrode and at a base of said optical waveguide ridge, including a region where the flat portion of the ridge is in contact with the exposed surface of said semiconductor substrate.

11. The optical modulator according to claim 1, further comprising a conductive layer of said first conductivity type disposed over a part of said semiconductor substrate including a region under said optical waveguide ridge and excluding the region where said first electrode is located, said second electrode being disposed on said semiconductor layer through the second opening in said dielectric film.

12. An optical modulator according to claim 1, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

13. An optical modulator according to claim 2, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

14. An optical modulator according to claim 3, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

15. An optical modulator according to claim 4, further comprising a high-resistance semiconductor layer located between one side of said optical waveguide ridge and said dielectric film, said high-resistance semiconductor layer being thinner than said optical waveguide ridge.

16. A photonic semiconductor device comprising:

an optical modulator having:

a semi-insulating semiconductor substrate with a principal plane including a partially exposed surface,

an optical waveguide ridge which is disposed on said semiconductor substrate and which includes a first cladding layer of a first conductivity type, an optical-absorption layer, and a second cladding layer of a second conductivity type, said optical waveguide ridge further having a side with a flat portion extending uniformly from a top of the ridge to said semiconductor substrate, the flat portion being in contact with the exposed surface of said semiconductor substrate,

a dielectric film which covers said optical waveguide ridge and said semiconductor substrate and which has a first opening at the top of said optical waveguide ridge and a second opening in a region of said semiconductor substrate other than the exposed surface,

a first electrode disposed on said dielectric film and mounted through the first opening on the top of said optical waveguide ridge, said first electrode further extending on the flat portion of said optical waveguide ridge in contact with a surface of said dielectric film, said first electrode further having one end on said semiconductor substrate at the exposed surface, and

a second electrode disposed on said semiconductor substrate and connected to the first cladding layer through the second opening in said dielectric film; and

a semiconductor laser device aligned in optical axis with the optical absorption layer of said optical modulator.

17. The photonic semiconductor device according to claim 16, wherein said semiconductor laser device is a ridge type device having an optical waveguide ridge disposed on a semi-insulating semiconductor substrate, said semiconductor laser device and said optical modulator being mounted on said substrate.

18. An optical modulator fabricating method including:

forming a first cladding layer of a first conductivity type, an optical absorption layer, and a second cladding layer of a second conductivity type on a semi-insulating semiconductor substrate;

forming by photolithography and etching an exposed surface of the semiconductor substrate as well as an optical waveguide ridge which has a side with a flat portion extending uniformly from a top of the ridge to the semiconductor substrate, the flat portion being in contact with the exposed surface of the semiconductor substrate;

forming a dielectric film over the semiconductor substrate and first and second openings through the dielectric film, the first opening being made at the top of the optical waveguide ridge, the second opening being made in a region of the semiconductor substrate excluding the exposed surface;

forming a first electrode through the first opening on the top of the optical waveguide ridge, extending on the flat portion of the optical waveguide ridge and in contact with a surface of the dielectric film, the first electrode further having one end on the semiconductor substrate at the exposed surface; and

forming a second electrode connected to the first cladding layer through the second opening in the dielectric film.

19. The optical modulator fabricating method according to claim is, wherein forming the exposed surface of the semiconductor substrate includes forming exposed

surfaces of the semiconductor substrate on both sides of said optical waveguide ridge, as well as the flat portion on both sides of the optical waveguide ridge, and wherein forming a first electrode includes forming the first electrode to extend over both sides of the optical waveguide ridge, the first electrode having two ends on the exposed surfaces of the semiconductor substrate.

20. The optical modulator fabricating method according to claim 18, wherein forming of the first cladding layer is preceded by forming a conductive layer of the first conductivity type over part of the semi-insulating semiconductor substrate, forming the exposed surface of the semiconductor substrate includes forming an exposed surface of the conductive layer while forming the exposed surface of the semiconductor substrate, and forming the second electrode includes forming the second electrode on the conductive layer through the second opening.